INFLUENCE OF DIETARY CRUDE PROTEIN ON POTENTIAL AMMONIA EMISSIONS FROM BEEF CATTLE MANURE

N.A. Cole, R. N. Clark, R. Todd, C. R. Richardson, A. Gueye, L. W. Greene, and K. McBride[1]

ABSTRACT

Atmospheric emissions of ammonia, as well as other gases and particulates are a growing concern of livestock producers, the general public and regulators. The concentration and form (rapidly degradable in the rumen vs. slowly degradable in the rumen) of protein in beef cattle diets may affect urinary and fecal excretion of nitrogen and thus may affect ammonia emissions from beef cattle feedyards. To determine the effects of dietary protein concentration and degradability on potential ammonia emissions, 54 steers were randomly assigned to 9 dietary treatments in a 3 x 3 factorial arrangement of treatments. Treatments consisted of three dietary crude protein concentrations (11.5, 13, and 14.5%) and three supplemental urea:cottonseed meal ratios (100:0, 50:50, and 0:100 of supplemental N). Steers were confined to tie stalls and feces and urine excreted were collected and frozen. One percent of daily urine and feces excretion were mixed and added to polyethylene chambers containing 1,550 g of soil. Chambers were sealed and ammonia emissions were trapped in an acid solution for seven days using a vacuum system. Results suggest that as the protein concentration in the diet increases from 11.5 to 13%, potential daily ammonia emissions increased 60 to 225 %, due primarily to increased urinary N excretion. As days on feed increased, in vitro ammonia emissions also increased. Potential daily ammonia emissions must be balanced with possible effects on animal performance to determine optimal protein concentrations and forms.

KEYWORDS. ammonia, air quality, emissions, beef cattle, feedyards, diet, protein

INTRODUCTION

Atmospheric emissions of ammonia, as well as other gases and particulates are a growing concern of livestock producers, the general public and regulators. Confined animal feeding operations, CAFOs, are implicated as a major contributor to these emissions. Most ammonia emitted from CAFOs is probably produced from the microbial breakdown of urinary urea to ammonia and carbon dioxide. Thus, factors that increase urinary N excretion could potentially increase ammonia emissions (Erickson et. al., 2000). However, factors such as urinary or soil pH and moisture content could also affect ammonia emissions (Luebes et. al., 1974).

Altering the concentration and form of nitrogen in the diet can potentially affect the quantity and form of nitrogen excreted by beef cattle. In general, as nitrogen intake increases, excretion of N as urea in urine increases (McBride et al., 2003). Also, as the ruminally degradable intake protein/ruminally undegradable intake protein increases, urinary N excretion tends to increase (Cecava and Hancock 1994; McBride et al., 2003). This study was conducted to determine the effects of dietary protein concentration and form on the potential ammonia emissions from manure of beef cattle fed high concentrate diets.

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Materials and Methods

All procedures were approved by the appropriate animal care and use committees at each institution.

Cattle and Diets

Fifty-four crossbred steers (avg wt 315 kg) were used in the study. Half of the steers were housed at the USDA-ARS/TAES experimental feedlot at Bushland, TX and the other half were housed at the Texas Tech University Research Center in New Deal, TX. All procedures were the same at both locations. Steers were randomly assigned to one of nine dietary treatments in a 3 x 3 factorial arrangement. Main treatment effects were three crude protein concentrations in the diets (11.5, 13, and 14.5% on a dry matter basis) and three supplemental urea:cottonseed meal ratios in the diets (100:0, 50:50, and 0:100 of supplemental N)(Table 1). All steers were halter-broken and adapted to individual tie stalls (1.2 x 2.5 m) and urine collection harnesses before the study began. Between nutrient balance trials steers were individually fed their treatment diets.

Table 1. Composition of experimental diets, % dry matter basis

Ingredient	11.5% CP			13.0% CP			14.5% CP		
	100:0[a]	50:50	0:100	100:0[a]	50:50	0:100	100:0[a]	50:50	0:100
Corn	79.68	77.84	75.90	79.12	75.22	71.25	78.58	72.70	66.75
Alfalfa	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Molasses	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Fat	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Urea	0.52	0.26	0.0	1.08	0.53	0.0	1.62	0.80	0.0
Cottonseed meal	0	2.0	4.1	0	4.25	8.5	0	6.40	12.80
Limestone	0.80	0.90	1.00	0.80	1.00	1.25	0.80	1.10	1.45
Supplement[b]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Chemical component									
DIP, %	6.58	6.27	5.98	8.17	7.52	6.92	9.69	8.73	7.83

[a] Urea:Cottonseed meal ratio (N basis).

[b] Contained 61.1% ground sorghum, 0.002% cobalt chloride, 0.15% copper sulfate, 0.0045% potassium iodide, 0.5% iron sulfate, 2% magnesium oxide, 0.75% manganese sulfate, 20% potassium chloride, 12.5% salt, 0.001% sodium selenite, 1% zinc sulfate, 0.3% vitamin E premix (227,000 IU/kg), 0.04% vitamin A premix (291 million IU/kg), 0.65% Tylan-40 (Elanco Animal Health, Greenfield, Indiana), and 1% Rumensin-80 (Elanco).

Three nutrient balance trials were conducted; one at the start (less than 30 days on feed), one near the middle (approximately 75 days on feed), and one near the end (greater than 100 days on feed) of the feeding period. Steers were confined in individual tie stalls (1.2 x 2.5 m) and were fitted with urine collection harnesses. Following a 3-day adaptation period, urine and fecal samples were obtained during the first 2 to 4 hours of collection on the first day to be used in the in vitro ammonia emission study. Feces and urine were collected for an additional 5-day period to determine average daily excretion. Urine and feces were frozen until used in the ammonia emission study.

In Vitro Ammonia Emissions

The in vitro ammonia emission system has been described previously (Shi et al., 2001). Briefly, the system was comprised of forty-eight sealed plastic chambers (20 cm x 20 cm x 12 cm deep) each attached to two ammonia trapping bottles containing 100 mL of 0.9 M sulfuric acid and a vacuum system to pull air through the chambers and traps at a rate of approximately 3 L/minute. To each chamber was added 1,550 g of screened soil followed by the feces and urine excretion of one steer (2 chambers / steer). The quantity of urine and feces added to each chamber was equal to 1% of the daily excretion by the steer during the nutrient balance trial. Because a total of nine ammonia runs were required, four chambers containing a common feces and urine were included in each run to correct for run-to-run variation in ammonia emissions caused by differences in temperature, atmospheric ammonia, air flow rate, or other factors. Two "blank" chambers containing soil but no feces or urine were included in each run to correct for atmospheric ammonia contamination.

Acid traps were replaced with fresh traps each day for 3 days then at 2-day intervals until day 7 of collection. At the conclusion of the run, the soil-feces-urine in each chamber was mixed and a sample was obtained and stored frozen for later laboratory analyses.

Laboratory Analyses

Feces and soil samples were analyzed for dry matter by drying to a constant weight at 60°C in a forced draft oven. The pH of urine was determined using a combination electrode. The pH of feces and soil were determined by mixing 5 g of soil or feces with 5 mL of RO water. The mixture was stirred, allowed to stand for1 minute, and the pH determined using a combination electrode. The N content of feces and urine was determined after wet digestion using a flow injection analyzer based on the automated procedure outlined by Technicon (1977). The N content of acid traps was also determined using the flow injection analyzer. The nitrate contents of the soil-feces-urine mixtures were determined by cadmium reduction using the flow injection analyzer.

Statistical Analyses

Data were analyzed as a split plot design with treatments in a 3 x 3 factorial arrangement of treatments using the Proc GLM procedure of SAS (1988). Factors included in the model were location (Bushland or Texas Tech), ammonia run (1 to 9), fecal collection period (start, middle, or end of feeding period), diet combinations, and appropriate interactions. Regressions of N applications vs ammonia emitted were determined using PROC REG of SAS.

Results and Discussion

Initial Collection Period - < 30 days on feed

The chemical composition and quantity of N added to each chamber (Table 2) varied with dietary regimen. As dietary CP concentration increased from 11.5 to 13% the quantity of urinary N applied increased ($P < 0.05$). Urinary N applied was not significantly different for steers fed the 13 and 14.5% CP diets. Ammonia emissions for steers fed the 11.5% CP diet were less ($P < 0.05$) than steers fed the 13 or 14.5% CP diets. Ammonia emissions were not significantly different for steers fed the 13 and 14.5% diets, possibly because of differences in the moisture content and because urinary N applications were not significantly different. Dietary urea content did not significantly affect urinary N application or ammonia emissions during the initial run.

Collection Period 2 - 75 days on feed

The effects of dietary CP concentration on ammonia emissions were similar to the initial run with steers fed the 11.5% CP diet having lower ($P < 0.05$) emission than steers fed the 13 or 14.5% diets (Table 3). As the concentration of urea in the diet increased, the quantity of urinary

N applied and the quantity of ammonia emitted increased ($P < 0.10$ or < 0.05).

Table 2. Chemical composition of feces and urine, quantity of N added, and cumulative ammonia N emitted during initial collection period (< 30 d on feed)

Item	Dietary protein, % DM			Urea:cottonseed meal			SEM
	11.5	13.0	14.5	100:0[a]	50:50	0:100	
Feces N, % DM basis	2.93[b]	3.09[c]	3.12[c]	3.04[bc]	3.00[c]	3.11[b]	0.02
Urine N, mg/100 mL	0.63[b]	0.64[b]	0.91[c]	0.74	0.77	0.67	0.03
Urine N added, total mg	32.5[b]	45.2[c]	52.8[c]	40.4	45.9	44.1	1.90
Cumulative NH3-N lost							
Day 7, mg	6.02[b]	19.60[c]	20.16[c]	15.33	15.49	14.96	1.30
N Lost, % of urine N	18.80[b]	35.5[c]	39.5[c]	34.50	28.10	31.2	1.89
Final pH	7.94[d]	7.94[d]	7.99[e]	7.97	7.96	7.93	0.011

[a] Urea:Cottonseed meal ratio in supplement (N basis).

[b,c] Means in same row and main treatment comparison without a common superscript letter differ ($P < 0.05$).

[d,e] Means in same row and main treatment comparison without a common superscript letter tend to differ ($P < 0.10$).

Table 3. Chemical composition of feces and urine, quantity of N added, and cumulative ammonia N emitted during second collection period (approximately 75 d on feed)

Item	Dietary protein, % DM			Urea:cottonseed meal			SEM
	11.5	13.0	14.5	100:0[a]	50:50	0:100	
Feces N, % DM basis	2.98[b]	3.15[c]	3.21[c]	3.08	3.11	3.15	0.028
Urine N, mg/100 mL	0.81[b]	0.91[b]	1.14[c]	1.03[d]	0.95[de]	0.88[e]	0.035
Urine N added, total mg	34.7[b]	51.3[c]	56.7[c]	51.1[d]	48.8[de]	42.8[e]	1.82
Cumulative NH3-N lost							
Day 7, mg	12.98[b]	34.66[c]	32.76[c]	29.03[c]	26.93[bc]	21.43[b]	1.75
N Lost, % of urine N	32.8[b]	58.7[c]	51.40[c]	51.00	46.5	45.4	2.56
Final pH	8.00	8.00	8.01	7.97	8.02	8.02	0.015

[a] Urea:Cottonseed meal ratio in supplement (N basis).

[b,c] Means in same row and main treatment comparison without a common superscript letter differ ($P < 0.05$).

[d,e] Means in same row and main treatment comparison without a common superscript letter tend to differ ($P < 0.10$).

Collection Period 3 - > 100 days on feed

The effects of dietary CP concentration on ammonia emissions were similar to the first two runs with steers fed the 11.5% CP diet having lower ($P < 0.05$) emission than steers fed the 13 or 14.5% diets (Table 4). As the concentration of urea in the diet increased, the quantity of urinary N applied, the quantity of ammonia emitted, and urinary pH increased ($P < 0.10$ or < 0.05).

Collection Period / Urinary N Effects

Cumulative ammonia-N losses increased as days on feed increased (Table 5: $P < 0.05$). This was due in part to greater urinary N applications as days on feed increased; however the proportion of urinary N lost also increased ($P < 0.01$). This may have been due in part to the higher ($P <$

0.01) urinary pH. As steers approach their market or mature weight, protein deposition decreases. Thus, if protein intakes remain near the same, as they did in this study, the proportion and quantity of dietary N excreted in the urine increases leading to increased ammonia emissions.

Table 4. Chemical composition of feces and urine, quantity of N added, and cumulative ammonia N emitted during final collection period (> 100 d on feed)

Item	Dietary protein, % DM			Urea:cottonseed meal			SEM
	11.5	13.0	14.5	100:0[a]	50:50	0:100	
Feces N, % DM basis	3.12[b]	3.04[b]	3.26[c]	3.11	3.14	3.18	0.023
Urine N, mg/100 mL	0.96[b]	1.07[bc]	1.23[c]	1.12	1.09	1.04	0.035
Urine N added, total mg	47.4[b]	70.3[c]	69.4[c]	69.2[b]	59.9[bc]	58.1[c]	2.51
Cumulative NH3-N lost							
Day 7, mg	28.72[b]	45.91[c]	44.16[c]	48.30[e]	31.63[d]	38.81[d]	2.35
N Lost, % of urine N	50.3[b]	63.1[c]	62.5[c]	64.3[c]	50.2[b]	61.3[c]	2.36
Final pH	8.08	8.06	8.08	8.03[b]	8.06[bc]	8.12[c]	0.118

[a] Urea:Cottonseed meal ratio in supplement (N basis).

[b,c] Means in same row and main treatment comparison without a common superscript letter differ ($P < 0.05$).

[d,e] Means in same row and main treatment comparison without a common superscript letter tend to differ ($P < 0.10$).

Table 5. Chemical composition of feces and urine, quantity of N added, and cumulative ammonia N emitted during each collection period

Item	Collection period (days on feed)			SEM
	< 30[a]	75	>100	
Feces N, % DM basis	3.05	3.12	3.14	0.15
Urine N, mg/100 mL	0.73[e]	0.95[f]	1.11[g]	0.022
Urine N added, total mg	43.5[b]	47.2[c]	62.8[d]	1.28
Cumulative NH3-N lost, mg				
Day 1	1.88[b]	2.31[c]	4.07[d]	0.12
Day 7	15.26[e]	25.51[f]	39.56[g]	1.19
N Lost, % of urine N	31.3[e]	47.3[f]	58.0[g]	1.45
Final pH	7.95[e]	8.00[f]	8.06[g]	0.008

[a] Approximate days on feed when feces and urine were collected.

[b,c,d] Means in same row without a common superscript letter differ ($P < 0.05$).

[e,f,g] Means in same row without a common superscript letter differ ($P < 0.01$).

For the 3 sampling periods, the overall regression equation for the relationship between urinary N applied (mg) and ammonia-N emissions (mg) after 7 days was as follows:

$$NH^3 \text{ emission} = 0.723(\text{urinary N}) - 10.29$$

with an r^2 value of 0.61 and P value < 0.001. Obviously, the quantity of urinary N excreted had a major effect on ammonia emissions in the present study. However, other factors also had a

major effect accounting for 39% of the variation in ammonia emissions. Regressions determined for the individual sampling periods indicated that as the days on feed increased, the slope of the regression equation (0.47, 0.69, and 0.76 for the first, second, and third periods, respectively) and the correlation coefficients (0.68, 0.72, and 0.81, respectively) increased.

Conclusion

These results demonstrate that potential daily ammonia emissions from beef cattle manure can be affected by the crude protein and urea concentration of the diet. However, under practical conditions, animal performance must also be considered. If dietary protein concentrations are decreased to a point that animal performance is adversely affected, then total ammonia emissions could actually be increased because animals require more days on feed to reach market weight and condition. Based on results of the complete N balance trial (McBride et al, 2003), and two performance trials (Duff et al., 2002), the actual CP requirement for optimal performance and maximal N retention using these diets was between 11.5 and 13% CP. As animals grow and mature, the crude protein required in the diet (as a % of DM) tends to decrease. Thus, when the same diet was fed throughout the feeding period potential ammonia emissions appeared to increase with days on feed. This suggests that the use of phase feeding could potentially decrease ammonia emissions from beef cattle feedyards; however factors such as animal health and performance must also be considered.

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Adsorption Process For Odor Emission Control At A Pilot Scale Dairy Manure Composting Facility

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Abstract

The odors emitted during the first 2 weeks of composting were conveyed into replicated adsorption reactors (3.8m x 7.2m), loaded with finished compost, to remove odors at a pilot scale composting facility. The initial composting material (50 m^3) consisted of dairy cattle manure and sawdust. Finished compost of the same volume filled the adsorption reactors. The ammonia emission during the first 72-h of composting decreased significantly (~ 94% , $P<0.01$,) with the adsorption treatment. Dimethyl disulfide was reduced significantly ($P<0.05$) with reduction rates ranging from 97% to 100%. However, n-valeric acid increased significantly ($P<0.05$) by the adsorption treatment. The ammonia concentration after the adsorption was still 2.5 times greater than the Japanese's lower-side regulation, thus the exhaust air from the adsorption reactor would still require to be diluted 2.5 times with fresh air to meet emission standards.

KEYWORDS. odor, ammonia emission, compost, adsorption, dairy manure

Introduction

The annual animal excretion in Japan was estimated by Chino et al. (1999) as 65 million ton of feces and 29 million ton of urine, with 94% of these materials recycled to farmland and grassland after drying or composting. Direct land application of livestock wastes is the most common option for waste management, although applying at higher rates than recommended could result in high phosphorous concentrations and odor problems (Lufkin et al. 1995). Composting decomposes organic biodegradable wastes effectively, making it attractive to the farming community (Leger et al., 1991). Composting reduces odor and thereby creates more desirable product for land application and when land applied less nutrients are susceptible to run off while providing similar amount of nutrients as liquid manure (Adler, 1998). Also, composting reduces the weight, moisture content and destroys pathogens (Rynk, 1992). Composting technologies can be classified as turned windrow, in-vessel system, natural aeration, passive aeration and forced aeration. Composting is completed when the compost-able materials have been completely converted to humus. Re-wetting the material and observing if it heats up again, which indicates

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